Module -3

Engineering materials & Nanochemistry

Alloys- An alloy is a homogeneous mixture of two or more than two metals. Alloy of mercury with other metals is called amalgams.

Purpose of making alloy –

1. To increase the resistance to corrosion
2. To increase the hardness of metal
3. To lower the melting point of metal
4. To modify the chemical activity of metal
5. To modify colour
6. To provide better castability

Some common alloys and their uses

	Name of alloy	Composition	Uses
1.	**Brass**	Cu – 60 -90% Zn – 40 -10%	Used for making utensils, parts of machinery, wires etc
2.	**Bronze**	Cu – 80 -95% Tin (Sn) – 20 -5%	Used for making statues, coins, cooking utensils etc
3.	**Solder**	Pb - 50% Sn – 50%	Used for soldering

Glass - Glass is an amorphous, brittle, transparent solid composed of a mixture of different silicates.

General Properties of Glass

1. Glass is amorphous
2. It can be moulded into any shape
3. It is brittle
4. It has no definite melting point
5. It is good electrical insulator
6. It can absorb, reflect or transmit light
7. It can be softened on heating
8. It is not affected by air, water or acids (except HF)
9. It is affected by alkalies.

Types of Glass

1. **Soda Glass (Ordinary Glass)** – It is a mixture of sodium silicate and calcium silicate. The raw materials used are sand, lime stone ($CaCO_3$) and sodium carbonate. They are cheap and softens at a lower temperature. Soda glass is used in making window glass, bottles, bulbs, jars etc.

2. **Borosilicate glass (Pyrex glass)** – This type of glass contain mixture of silicates of sodium, aluminium and boron. It can withstand high temperature and has low coefficient of expansion. It is resistant to chemicals and is used to make laboratory glass wares and kitchen wares.
3. **Safety Glass** – It is used in making wind screens of automobiles and aeroplanes. It is prepared by placing a layer of transparent plastic between two layers of glass by means of suitable adhesive.
4. **Insulating Glass** – It is prepared by two or more plates of glass separated by 6 to 13mm gap filled with dehydrated air and sealing around the edges. This air gap provides high insulation against heat.

REFRACTORIES

Refractories are material which can withstand high temperature without softening, melting or deformation. Eg. Alumina, Silica, Magnesia bricks etc.

General Properties of Refractories

1. It should be infusible – The softening temperature must be higher than the operating furnace temperature.
2. They must be chemically inert
3. It should have low porosity
4. It should have sufficient resistance to thermal spalling (spalling refers to disintegration at high temperature or by sudden change in temperature)
5. It should have low thermal expansion
6. It should have high strength
7. It should have low electrical conductivity

Classification of Refractories- Refractories are classified in to three types based on chemical nature.

1. **Acid Refractories**- They are stable to acids but attacked by bases. Eg. Silica, Alumina
2. **Basic Refractories** – They are stable to alkalies but attacked by acids. Eg. Magnesite, Dolomite, Bauxite.
3. **Neutral Refractories** – These are not attacked by slightly acidic or basic materials. Eg. Chromite, Silicon carbide (carborundum), Graphite etc.

Refractory materials are used in furnaces, kilns, incinerators, and reactors. Refractories are also used to make crucibles and moulds for casting glass and metals.

Polymers – Polymers are high molecular mass compound(Macromolecules) which are formed by joining very large number of one or more type of simple molecules.

Monomers are the simple molecules which built up to form the polymer.

Polymerisation – It is the process of chemical combination of monomers to form the polymer.

Classification of Polymers- Based on nature of monomers

Homopolymers -Polymers consisting of single type of monomer molecules are known as homopolymers. It can be represented as –A-A-A-A-A-A-A- Eg. Polythene (monomer – ethylene), PVC (monomer – vinyl chloride) etc

Copolymer- Polymers consisting of more than one type of monomers are called copolymers.

Copolymer can be represented as -A-B-A-B-A-B-A-B-

Eg. Nylon-6,6 (monomers – hexamethylene diamine and adipic acid),

Dacron(monomers- ethylene glycol and terephthalic acid)

Classification of Polymers- Based on Mode Polymerisation

Addition polymers - The polymers formed by the repeated addition of monomer units are called addition polymers. These polymers are also called Chain growth polymers. Eg. Formation of poly ethene from ethene, formation of PVC from vinylchloride, formation of teflon etc.

Condensation polymers – The polymers formed by repeated condensation reaction between the monomer units are called condensation polymers. Eg. Bakelite, polyester, Nylon66, Terylene etc.

Difference between addition polymerisation and condensation polymerisation

Addition polymerisation	**Condensation polymerisation**
1. It is due to the repeated addition of monomer units. 2. Monomers usually contain one or more double bonds 3. The monomer and polymer have same empirical formula 4. Polymerisation is due to chain growth Eg. Formation of polythene PVC, teflon	1. It is due to the series of condensation reaction between the monomer units. 2. Monomers usually contain two functional groups 3. The monomer and the polymer have different empirical formulae. 4. Polymerisation is due to step growth Eg. Formation of Nylon 6,6, bakalite, dacron

Classification of Polymers- Based on Molecular forces

Elastomers – Polymer chains are held together by weak intermolecular forces. Eg. Rubber, Buna-S, Buna-N etc.

Fibres – Polymer chains are held together by strong intermolecular forces are called fibres. Eg. Nylon 66, Terylene

Plastic – Plastic may be defined as organic material of high molecular mass which can be moulded into any desired shape by subjecting to suitable heat and pressure conditions.

Plastics are of two types-

1. Thermoplastics – Plastics which can be softened on heating and hardened on cooling are called thermoplastics. Repeated heating and cooling do not alter their chemical nature as the changes are physical in nature. Eg. PVC, polythene, Cellulose acetate etc

2. Thermosetting plastics – These are plastic polymers which become infusible and hard on heating. They cannot be remelted and remoulded as the change is permanent.

Eg. Bakelite, polyesters, silicones etc.

Differences between thermoplastics and thermosetting plastics

Thermoplastics	Thermosetting plastics
1. It can be remoulded and reshaped many times by applying heat and pressure 2. It becomes soft on heating and hard on subsequent cooling. 3. These are linear polymers 4. They are formed by addition polymerisation 5. They are soft, weak and less brittle	1. It cannot be remoulded and reshaped by applying heat and pressure 2. It becomes hard and decomposed on heating. 3. These are cross linked polymers 4. They are formed by condensation polymerisation 5. They are hard, strong and brittle

Rubber -

Natural rubber – It is an elastic material obtained from the sap (latex) of the rubber tree. The latex is treated with a dilute solution of formic acid or acetic acid, when coagulation of rubber particle takes place. Chemically natural rubber is a linear polymer of **isoprene** (2-methyl1,3- butadiene)

Natural rubber is a soft gummy and sticky mass. It is insoluble in water, dilute acids, and alkalies but soluble in organic solvents like benzene, chloroform, petrol etc. natural rubber has low tensile strength, and low elasticity.

Vulcanisation – It is the process of heating natural rubber with sulphur (3-5%) at a temperature of 110-140^{o}C. Vulcanisation improves the elasticity and tensile strength of natural rubber. During vulcanisation the sulphur atoms bridges or crosslinks between rubber chains. Crosslink makes rubber hard and stronger.

Merits of vulcanisation-

1. Vulcanisation helps in preventing the slippage of rubber chains on application of stress.
2. It makes rubber less sensitive to temperature changes.
3. It increases elasticity and tensile strength.
4. It increases the resistance of rubber to oxidation, abrasion, wear and tear, water and organic solvents.
5. Vulcanisation increases the electrical resistance of rubber.

Common Polymers, Monomers and uses

Polyethene	Ethene	Buckets, containers, bottles, pipes, toys, packaging material
PVC	Vinyl chloride	Sheets, rain coats, hand bags, dolls, pipes, table cloths, Vinyl floorings
Bakelite	Phenol and formaldehyde	Combs, fountain pen, binding glue, handles of utensils, Electrical switches etc
Nylon-6,6	Hexamethylene diamine and adipic acid	Carpets, ropes, tyre cords, fabrics, bristles for brushes etc.

Buna -S	Butadiene and styrene	Hoses, tyres, floor tiles, shoe soles etc
Buna – N	Butadiene and vinyl cyanide	Conveyer belts, fuel tanks, hoses, printing rollers

NANOCHEMISTRY

Nanomaterials are materials with any one external dimension in the range of 1nm - 100 nm

Nano chemistry is the study of materials of the size 1 to 100nm range (1nm = 10^{-9}meter).

Nanotechnology is the synthesis, analysis, and characterization of materials at the nano scale (1-100nm)

Examples of some nano sized materials are

DNA width ≈ 2nm, H – atom = 0.1nm, Bucky ball = 1nm, Carbon nano tube ≈ 1.3nm

Zero Dimensional (0D) nanomaterials - Nanomaterials with all the three dimension (length, breadth and thickness) in the nanoscale range is called Zero Dimensional (0D) nanomaterials. Eg- Quantum dots, Fullerene etc.

One Dimensional (1D) nanomaterials - Nanomaterials with any two dimension in the nanoscale and the third dimension in the macro scale (above 100 nm) is called One Dimensional (1D) nanomaterials. Eg- Carbon nanotubes (CNT), nano wires etc.

Two Dimensional (2D) nanomaterials - Nanomaterials with any one dimension in the nanoscale and the other two dimension in the macro scale (above 100 nm) is called Two Dimensional (2D) nanomaterials. Eg- Nano sheets, nano coatings etc.

Carbon nanotubes are allotropes of carbon. (CNTs- are also known as buckytubes). A carbon nanotube is a structure which seems to be formed by rolling a sheet of graphite into the shape of a cylindrical tube. The two varieties of carbon nanotubes are

- **SWNT – S**ingle walled carbon nanotube- it consists of a single cylinder of graphite sheet
- **MWNT** – Multi walled carbon nanotube – it consists of multiple concentric nanotube cylinders.

Fullerene- Fullerenes are allotropes of carbon consisting of spheroidal molecules of carbon with composition C_{2n} (where n ≥ 30). The most common member of this category is **Buckminster fullerene** with formula $\mathbf{C_{60}}$.

Graphene – Graphene is a one atom thick layer of graphite. It is a two dimensional crystal of carbon atoms arranged in a honeycomb lattice. Graphene is the most reactive form of carbon and is a very good conductor of electricity.

Applications of Nano materials

1. Due to large surface area nanomaterials act as better catalyst. Eg.TiO_2, Al_2O_3, and ZrO_2
2. Tumors can be detected, located and treated with very high accuracy
3. DNA mapping of new born child
4. Nanoparticles are used to identify protein-protein interaction.
5. Targeted drug delivery in the body.
6. Bio-compatible joint replacements.
7. Carbon nanotubes are used as heat conductors.
8. Carbon nanotubes are used in solar cells.